"On the Dielectric Constants of certain Frozen Electrolytes at and above the Temperature of Liquid Air."

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In a preliminary note on the "Dielectric Constant of Ice and Alcohol at very Low Temperatures"* we have described the method employed by us in determining the dielectric constants of ice and frozen ethylic alcohol at the temperature of liquid air. One difficulty which presented itself in our initial experiments was that of the construction of a suitable electrical condenser for use with frozen liquids as dielectrics. The concentric-tube pattern of condenser used by us in the first experiments on ice gave trouble by becoming deformed under the expansive force of the water on freezing, and the subsequent great contraction of the ice on cooling to the tempera- of liquid air tended to break the contact between the metal plates and the dielectric. It was, in addition, difficult to clean out.

In undertaking, therefore, a more careful study of the dielectric constants of various frozen electrolytes at and above the temperature of liquid air, the first experimental problem which arose was that of the construction of a form of condenser which could be employed with the selected frozen electrolyte as dielectric, and which should comply with the following conditions:—

1. To allow any required and actual expansion of the dielectric on freezing without deforming the condenser.
2. To permit the subsequent great contraction of the dielectric substance on cooling to the temperature of liquid air, without breaking contact between the dielectric and the metal plates.
3. To be sufficiently compact to be placed in a large vacuum tube of liquid air.
4. To be rigid and have high insulation and be able to be taken apart and put together again quickly and accurately.

After trying several arrangements, we were at last able to design a condenser fulfilling the above conditions in a very perfect way, and which has given in its latest form little or no trouble in work.

This condenser, which we call a cone-condenser, is constructed as follows:—

It consists of two hollow cones turned out of hard brass (see fig. 1), the outer cone being 14·9 cm. in length inside, 5·1 cm. in diameter

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* See 'Roy. Soc. Proc.,' vol. 61, p. 2, February, 1897. J. Dewar and J. A. Fleming.

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inside at the top, and 2·6 cm. inside diameter at the bottom. The bottom of the outer cone is closed by a brass plate fastened on with six set screws, and which plate carries a small ebonite steady pin 1·5 cm. long and 3 mm. in diameter, screwed into the centre. In some instances a quartz pin is preferable, and can be used.

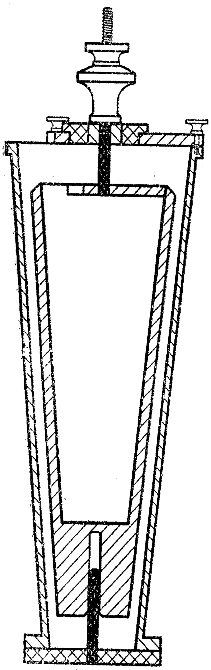

Fig. 1.—Electrical cone condenser for low temperature measurement of dielectric constant.

The inner cone is also closed at the bottom and open at the top. The two cones were accurately ground together and, after finishing, were thickly gilt.

The inner cone is 12·7 cm. in length and 4·8 cm. in diameter on the outside at the top, and 2·6 cm. across the bottom. The bottom of the inner cone is closed by a thick plate having a recessed hole in it, into which the above-mentioned ebonite pin fits easily, and acts as a steady-pin to keep the two cones coaxial. To the top of the inner cone is fixed, by means of a three-spoke carrier, a vertical screw pin, and this screw passes through a metal boss in the centre of an ebonite bushing piece fixed in the middle of another three-spoke carrier fastened by three removable screws to the upper edge of the outer cone.

By means of a nut on the screw, the inner cone can be displaced coaxially with the outer cone, so as to leave between the cones a conical space into which any fluid can be introduced. A lock nut enables the inner cone to be fixed.

The inner and outer cone then form the two plates of the condenser, and the fluid, or frozen fluid in the conical interspace, the dielectric. The total surface of the inner cone is 147·6 sq. cm. The cross section of the ebonite steady-pin is, therefore, only about one fifteen-hundredth of the total exposed surface of the condenser, and any correction for its dielectric constant may be neglected. The weight of the whole condenser is 960 grams.

The thickness of the walls of the two brass cones is about 2 mm. in each case.

It will be seen, therefore, that if any fluid is introduced between the cones and frozen, any expansion thereby taking place lifts the inner cone, but does not in any way deform the condenser. If, then, on cooling, a subsequent contraction takes place, the weight of the inner cone makes it fall back and follow up the shrinking dielectric. And to assist this a small spiral spring is placed around the central screw between the three-spoke carriers attached to the inner and outer cones. After the liquid is frozen, if desired, the nut working on the screw pin may be loosened, the inner cone is then free to follow up the contraction of the dielectric and always keeps up a perfect contact between the metal cones and the conical layer of dielectric. The whole arrangement is perfectly rigid, and can be taken to pieces, and put together again in exactly the same position by releasing the three screws which attach the three-spoke carrier to the outer cone.

In order to determine the temperature of the frozen dielectric a platinum wire thermometer was fixed in the interior of the inner cone with the wire pressed against the wall of the cone, and was held there by partly filling the interior of the inner cone with paraffin wax or fusible metal. Leading-in wires were then brought out to enable the resistance, and therefore the temperature of this platinum thermometer, to be instantly determined on a slide wire bridge.

The condenser was then suspended in such a way by silk strings that it could be lowered into the interior of a very large vacuum vessel, 60 cm. deep and 7 cm. wide in interior diameter, and capable of holding several litres of liquid air. The two cones of the condenser were connected with the galvanometer, battery and vibrating contact maker controlled by an electrically driven tuning-fork, just as described in a previous communication.*

The arrangement of circuits is shown in fig. 2.

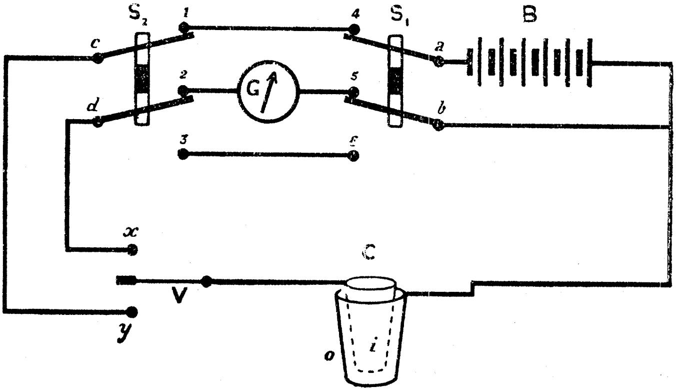

Fig. 2.—Arrangement of connections for measurement of dielectric constants. B, Battery of lithanode cells. G, Galvanometer. S_1S_2, Change-over switch. C, Cone condenser. V, Vibrating contact maker.

By means of a switch S_1S_2 the position of the galvanometer can be instantly changed from the *charge* to the *discharge* circuit, so as to show if the rapid series of charges of the condenser gives a current exactly equal to the rapid series of discharges. When this equality exists we know that there is no sensible leakage current passing through the condenser dielectric, or loss of charge during the interval of time which elapses between two successive contacts of the vibrating switch.

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* See a "Note on the Dielectric Constant of Ice and Alcohol at very low Temperatures," 'Roy. Soc. Proc.,' vol. 61, p. 2, February, 1897.

This disposition of apparatus enabled us therefore very quickly—

(1) To measure the capacity of the condenser when having any selected frozen liquid as dielectric at any temperature.
(2) To measure the resistance of the above dielectric.
(3) To determine the temperature of the dielectric layer.
(4) To heat up the whole condenser slowly to any temperature above that of liquid air.
(5) To determine whether there was any sensible leakage current through the dielectric.

The usual method of procedure, after having filled the condenser with the electrolyte to be examined, was to cool down the whole condenser to the temperature of liquid air by slowly immersing it in several litres of liquid air contained in the large vacuum tube. Then it was raised out into the cold gaseous air lying above the surface of the liquid air, in which position the whole condenser rose very slowly in temperature from $-185°$ C. up to the melting point of the dielectric, and during this time observations for capacity, resistance, and temperature were successively and quickly taken at various temperatures.

The great mass of the condenser favoured a very slow temperature change, and thus assisted to keep all parts of the condenser at the same temperature.

The operation of measuring the dielectric constant of the frozen electrolyte placed in the condenser consisted then in measuring the current flowing through the galvanometer with a constant switch-frequency, and charging voltage, when the condenser had the selected electrolyte as its dielectric; and then again when the frozen electrolyte was melted out and the condenser put together with the cones the same distance apart and at the same temperature but having gaseous air as the dielectric. As a matter of fact, each time of experimenting one careful measurement was made of the charge and discharge current through the condenser set up with the cones a fixed distance apart and the cones cooled to the temperature of liquid air, the dielectric being gaseous air of the same temperature. The capacity of the condenser, when the vertical distance separating the cones was 1·5 mm., was very nearly 1/8000th of a microfarad, with air as dielectric. Under these circumstances the multiplication of the observed galvanometer deflection by a factor, after applying a correction for the capacity of the leads and vibrator, suffices to reduce the galvanometer reading to the value of the dielectric constant of the dielectric used referred to that of gaseous air as unity.

The galvanometer used in these experiments was a Holden-Pitkin galvanometer with movable coil. The scale was placed 125 cm. from the mirror, and the sensibility was such that an electromotive force of 1·434 volts, acting through a megohm, gave a scale deflection of 3·6 cm.

In making the measurements a careful watch was kept to see if the charge current of the condenser was always equal to the discharge current; and the moment the charge and discharge galvanometer deflections differed by anything like a millimetre or two of scale deflection (the scale being 125 cm. from the galvanometer) the capacity measurements were no longer trusted. Moreover, at intervals, a large resistance of several thousand ohms was inserted in the galvanometer circuit to ascertain if there was any variation of deflection. The absence of any change in deflection was also taken as the proof that no sensible leakage current was passing through the dielectric, and polarisation practically absent.

From the construction of the condenser it will be seen that a considerable vertical movement of the inner cone only changes the perpendicular distance between the surfaces of the cones by about one-tenth of the vertical rise. When a liquid is placed between the cones and frozen there is a change of distance due to the lift of the inner cone. We have, however, convinced ourselves by experiment that the change in the capacity of the condenser which may occur owing to change in the bulk, either expansion or contraction, of the dielectric cannot make more than 5 per cent. change in total capacity measured. This is not more than may easily occur through unavoidable degrees of impurity in the dielectrics used. We have not thought it necessary to apply a correction for the change in dimensions of the dielectric thickness on cooling.*

In reducing the observations a correction has been made for the capacity of the connecting wires and for that of the vibrating contact maker,† and in the following tables the reduced and corrected value is given of the dielectric constant of the various electrolytes used, the dielectric constant of air at ordinary pressure and temperature being taken as unity. Temperatures are all given in terms of our standard platinum thermometer P_1.*

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* There is also a correction due to the fact that some of the lines of electrostatic induction start from the inside of the inner cone and terminate on the carrier or other portions of the outer cone. In other words the whole of the capacity of the system is not comprised between the opposed surfaces of the cones. This, however, is not a large correction, as we have found that even if it is omitted we obtain results for the values of certain well-known dielectric constants closely agreeing with those of other observers. Our object in these experiments has not been so much to obtain great numerical accuracy of value as to determine the general mode of variation of the dielectric constant with temperature.

† See 'Roy. Soc. Proc.,' vol. 61, p. 12, Dewar and Fleming, "On the Dielectric Constant of Ice and Alcohol at very low Temperatures."

The temperature at which the observations are interrupted in the case of each electrolyte depends upon the temperature at which sensible electric conductivity makes its appearance. One of the most remarkable facts which has attracted our attention in these experiments is that electric conductivity in electrolytes which are frozen and then reduced to very low temperatures extends far down into the solid condition, but there is for each body apparently a temperature at which electric conductivity begins to increase very rapidly, so much so, that in some cases a rise of temperature of only two or three degrees makes all the difference between being able to measure the dielectric constant well by the above-described method and not being able to measure it at all.

At the lowest temperatures reached, all the frozen electrolytes we have used appear to be practically perfect insulators, or, at any rate, to have enormously high electric resistivity, and then, as they are gradually heated up, long before their melting point is reached, quite suddenly they begin to exhibit very sensible conductivity. We have not attempted to interpret this result into the language of any theory of electrical conduction, but it is evidently a very important fact in connection with electrolytic conduction.

Hence, in the above described observations, a point of temperature is reached for each frozen electrolyte as it warms up, at which, for the frequency of charge and discharge (viz., 120 per second) we were using, further observation on the dielectric constant became impossible, at least by the method employed. Cases in which the true dielectric measurement is doubtful, owing to such incipient conduction, are indicated by a query.

The following measurements have, then, been made on certain well known electrolytes frozen as described :—

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* See "Thermo-electric Powers of Metals and Alloys," Dewar and Fleming, 'Phil. Mag.,' July, 1895, p. 100.

Dielectric Constant of Sulphate of Copper.

(10 per cent. solution.)

Frequency of contact-maker 121. Galvanometer deflection when condenser has air as dielectric = 3·91 cm. for 100 volts.

Temperature in platinum degrees.	Galvanometer deflection in centimetres.	Dielectric constant.	Observations.
−199·4	10·38	2·57	Charging volts 100·4.
−163·0	19·25	4·43	
−133·2	12·70	16·40	Charging volts 19·7.
−125·2	1·25	22·20	Charging volts 1·43.
−117·5	2·45	43·80	Condenser warmed up in air out of the vacuum vessel.
−110·7	3·45	61·50	
−93·3	7·90	142·0 ?	
−87·8	9·84	174·0 ?	

Dielectric Constant of Potassic Cyanide.

(5 per cent. solution.)

−197·2	11·45	2·85	Charging volts 100·4.
−168·8	1·35	24·10	Charging volts 1·43.
−162·8	1·95	34·80	Condenser warmed up in air out of vacuum vessel.
−139·1	9·15	163·0 ?	

Dielectric Constant of Perchloride of Iron.

(Saturated solution.)

−198·8	13·37	3·34	Charging volts 100·4
−162·7	14·25	3·56	
−144·9	15·65	3·91	
−133·8	3·33	4·23	Charging volts 19·8.

The above observations are set out in curves in fig. 3.

It will be seen that in each of the above three instances the dielectric constant falls to a value, near to 3, at the temperature of liquid air, but rises very rapidly in the case of the potassic cyanide solution, less rapidly in the case of the copper sulphate solution, and still less fast in the case of the ferric perchloride solution as the temperature rises.

As regards the electrical resistance, the following tables show approximately the kind of variation which takes place, but these figures are only approximations; they include the leakage of the leads and vibrating contact maker, which, though very highly insulated, are not infinite in resistance. Hence these figures merely show the

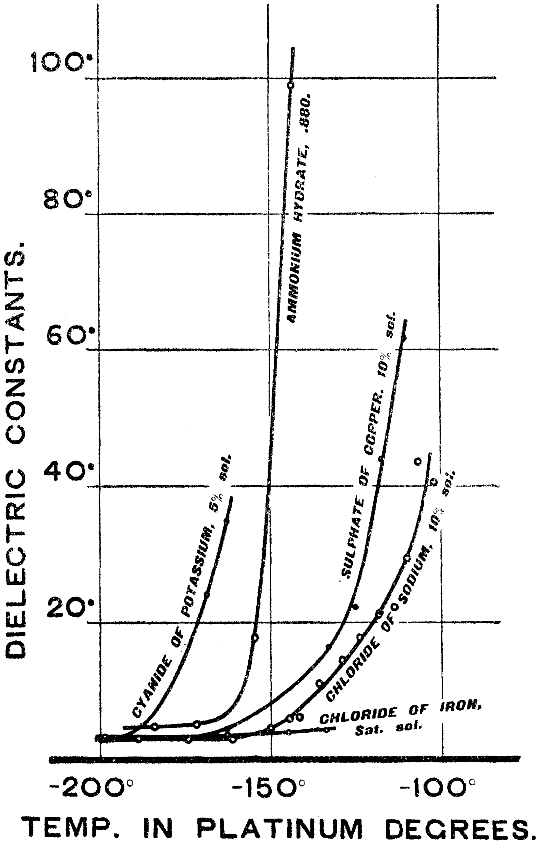

FIG. 3.—Curves showing the variation of dielectric constant of electrolytes with temperature.

probable order of magnitude of the resistance of the condenser and its mode of variation with temperature.

Resistance in Megohms of the Condenser containing various Frozen Electrolytes.

Sulphate of Copper.

(10 per cent. solution.)

Temperature in platinum degrees.	Resistance in megohms.
−200	greater than 10,000·0
−144	about 500·0
−99	about 25·0
−80	about 0·1

Potassic Cyanide.

(5 per cent. solution.)

Temperature in platinum degrees.	Resistance in megohms.
−197	greater than 2500·0
−147	about 4·0
−127	about 0·2

Perchloride of Iron.

(Saturated solution.)

−198	greater than 10,000·0
−156	about 10,000·0
−115	about 0·2

The above figures show with what great rapidity the resistance falls, when once a certain temperature is reached, which, however, is far below the melting point of the frozen electrolyte.

Further experiments were then made on chloride of sodium, hydrochloric acid, sulphuric acid, and ammonium hydrate solutions.

Dielectric Constant of Chloride of Sodium.

(10 per cent. solution.)

Frequency of contact maker 120. Galvanometer deflection when condenser has air as dielectric = 3·45 cm. for 100 volts.

Temperature in platinum degrees.	Galvanometer deflection.	Dielectric constant.	Observations.
−198·7	2·11	2·87	Charging volts 20·2.
−197·8	10·86	2·96	Charging volts 102·2.
−188·8	10·85	3·06	
−174·2	10·88	2·94	
−161·3	10·02	2·99	
−150·2	16·35	4·52	
−144·7	21·30	5·97	
−141·7	4·39	6·15	Charging volts 20·2.
−136·0	7·85	11·10	
−129·2	10·25	14·55	
−124·2	12·55	17·85	
−118·5	14·72	21·20	
−114·0	1·10	22·30	Charging volts 1·43.
−110·2	1·45	29·30	
−106·6	2·09	43·50	
−102·0	2·00	40·40	
−92·2	3·50	65·60 ?	

At the last observation, 10,000 ohms taken out of galvanometer circuit increased the galvanometer deflection by 2 mm., showing that conductivity had begun.

Dielectric Constant of Ammonium Hydrate.

(Ordinary laboratory solution 0·88 sp. gr.)

Frequency of contact maker 120. Galvanometer deflection with air as dielectric = 2·43 cm. for 100 volts.

Temperature in platinum degrees.	Galvanometer deflection in centimetres.	Dielectric constant.	Observations.
−184·2	12·35	4·82	Charging volts 101.
−171·8	12·92	5·06	
−154·8	8·70	17·80	Charging volts 20.
−143·5	3·45	98·80	

The curves for the sodium chloride 10 per cent. solution and 0·880 ammonia are given in fig. 3.

Dielectric Constant of Ammonium Hydrate.

(Dilute solution 1/100th gram molecule per litre.)

Galvanometer deflection with air as dielectric = 2·60 cm. for 100 volts.

Temperature in platinum degrees.	Galvanometer deflection in centimetres.	Dielectric constant.	Observations.
−198·0	6·97	2·47	Charging volts 100·8.
−198·1	6·97	2·47	
−169·5	7·00	2·48	
−148·2	9·85	3·78	

It will be seen that the dielectric constant of the strong solution of ammonium hydrate increases much faster than that of the very dilute solution with rise in temperature.

Hence it was considered desirable to obtain an approximation to their resistances.

Ammonium Hydrate, sp. gr. = 0·880.

Electrical resistance of condenser.

Temperature in platinum degrees.	Resistance of condenser in megohms.
−180	greater than 10,000·0
−149	about 280·0
−137	about 17·0
−128	about 0·8

Ammonium Hydrate.

1/100th of gram molecule to the litre.

Electrical resistance of condenser.

Temperature in platinum degrees.	Resistance of condenser in megohms.
−198	greater than 50,000
−140	about 91

In the next place solutions of mineral acids were tried, taking sulphuric acid and hydrochloric acid as typical, and operating with them as above when frozen as the dielectric of the condenser.

Dielectric Constant of Dilute Sulphuric Acid.

(10 per cent. solution.)

Frequency of contact maker 120. Galvanometer deflection with air as dielectric = 3·45 cm. for 100 volts.

Temperature in platinum degrees.	Galvanometer deflection in centimetres.	Dielectric constant.	Observations.
−202·2	2·86	4·11	Charging volts 20·1.
−197·8	2·84	4·07	
−197·5	2·84	4·07	
−190·0	2·87	4·14	
−169·8	3·00	4·21	
−158·0	4·05	5·72	
−146·8	6·30	9·00	
−142·8	8·48	12·12 ?	

Dielectric Constant of Dilute Hydrochloric Acid.

1/100th of gram molecule to the litre.

Galvanometer deflection with air as dielectric = 2·60 cm. for 100 volts.

−198·0	6·96	2·46	Charging volts 100·8.
−196·2	6·96	2·46	
−194·3	6·96	2·46	
−176·2	8·20	2·94	

The curves representing the dielectric constants of sulphuric and hydrochloric acids and dilute ammonia are given in fig. 4, which contains some other curves as well.

In the case of this dilute hydrochloric acid, the resistance of the condenser at −198° was greater than 50,000 megohms, and at

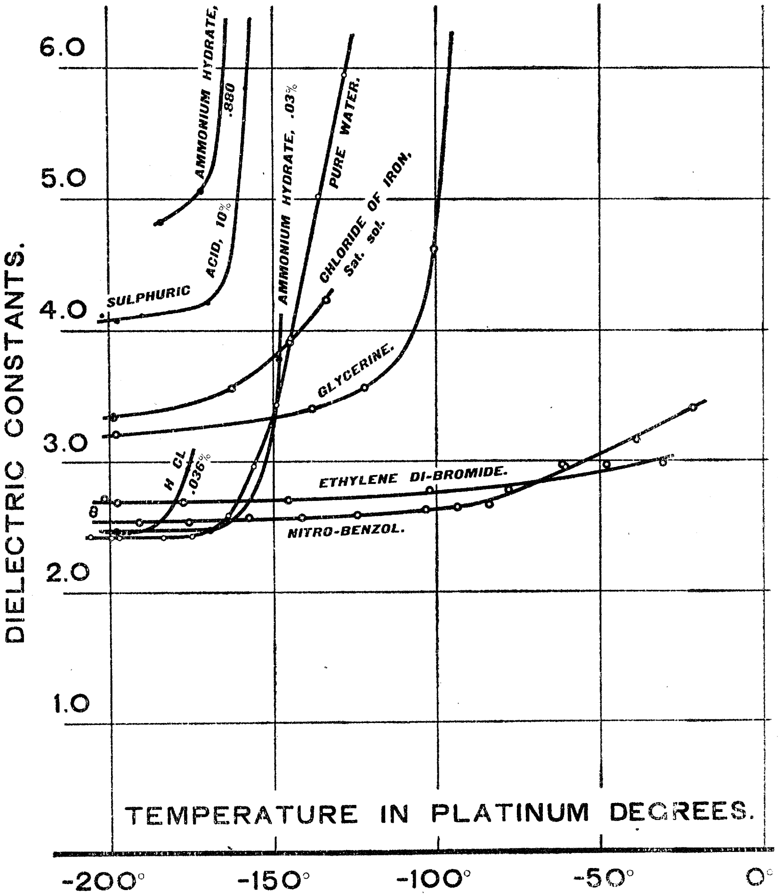

Fig. 4.—Curves showing the variation of dielectric constant of various frozen liquids with temperature.

—162° not more than 5·4 megohms. Hence there was an enormous fall between —198° and —162°.

Broadly speaking, it will be seen that in all the above cases, for the electrolytes employed, the dielectric constant of the solution, whether strong or weak, when frozen and reduced in temperature to —200°, was represented by a number not very different from that of the dielectric constant of pure ice at the same temperature; and hence it appears clear that the conductivity of the electrolytic solution at the ordinary temperature, when liquid, exercises very little influence upon the dielectric constant of the electrolyte when frozen and reduced to the temperature of liquid air. It is clear, also, that there is a temperature for each electrolyte at which the dielectric constant and the conductivity begin to increase with great rapidity, the conductivity especially beginning with marked suddenness.

Attention was next directed to the caustic alkalis, potash and soda. Solutions of these bodies of various concentrations were employed, and the results of the observations are shown in the following table and set out in the form of curves in fig. 5.

Dielectric Constant of Potassic Hydrate.

(50 per cent. solution.)

Frequency of contact maker 120. Galvanometer deflection with air as dielectric = 2·60 cm. for 100 volts.

Temperature in platinum degrees.	Galvanometer deflection in centimetres.	Dielectric constant.	Observations.
−203·2	8·23	15·6	
−149·8	12·00	22·9	
−135·6	14·57	27·8	

Solution of Potassic Hydrate.

(20 per cent. solution.)

Galvanometer deflection with air as dielectric = 3·91 cm. for 100 volts.

−201·5	2·31	41·2	Charging volts 1·434
−198·7	2·55	45·6	
−180·0	2·60	46·4	
−162·3	2·75	48·9	

In these observations 90,000 ohms were alternately placed in series with, or removed from, the condenser circuit, without producing any change in the galvanometer deflection, thus showing absence of any sensible leakage current through the condenser.

Solution of Potassic Hydrate.

(10 per cent. solution.)

Galvanometer deflection with air as dielectric = 3·36 cm. for 100 volts.

Temperature in platinum degrees.	Galvanometer deflection in centimetres.	Dielectric constant.	Observations.
−203·4	3·05	63·0	Charging volts 1·434.
−202·5	3·26	67·2	
−200·8	3·65	75·2	
−197·2	4·29	87·5	
−179·0	4·34	89·7	
−170·9	4·40	90·8	
−159·6	4·43	91·5	
−150·2	4·49	92·7	
−141·1	4·60	95·0	
−129·5	4·81	99·0	
-117·4	13·2	272· ?	

Solution of Potassic Hydrate.

(5 per cent. solution.)

Galvanometer deflection with air as dielectric = 3·91 cm. for 100 volts.

−204·8	6·92	123	Charging volts 1·434.
−200·7	7·07	126	
−196·2	7·35	131	
−181·5	7·55	135	
−170·1	7·49	133	
−158·7	7·33	131	
−147·3	7·40	132	
−135·9	7·54	134	
−127·7	8·01	143	

Solution of Potassic Hydrate.

($2\frac{1}{2}$ per cent. solution.)

Galvanometer deflection with air as dielectric = 2·56 cm. for 100 volts.

−201·0	10·3	20·8	Charging volts 20·0.
−166·0	14·2	29·0	
−137·2	1·6	45·5	Charging volts 1·434.

Solution of Potassic Hydrate.

(0·05 per cent. solution.)

1/100th of gram molecule per litre.

Temperature in platinum degrees.	Galvanometer deflection in centimetres.	Dielectric Constant.	Observations.
−203·4	5·52	10·7	Charging volts 19·8.
−201·5	6·11	11·9	
−196·0	7·60	14·7	
−179·0	8·30	16·2	
−169·5	8·78	17·1	
−158·2	9·60	18·8	
−152·0	10·22	20·0	
−141·2	12·20	23·9	
−132·1	17·90	35·1	
−120·3	1·85	50·2 ?	Charging volts 1·43.

In the next place the same experiments were repeated, using caustic soda solution in water instead of caustic potash.

Dielectric Constant of Sodic Hydrate.

(Saturated solution.)

Galvanometer deflection with air as dielectric in the condenser = 3·15 cm. for 100 volts.

−201·8	4·55	7·02	Charging volts 20.
−181·8	4·60	7·08	
−146·7	5·00	7·70	
−102·2	6·60	10·20	
−91·8	14·75	23·10	

Solution of Sodic Hydrate.

(10 per cent. solution.)

Galvanometer deflection with air as dielectric = 3·45 cm. for 100 volts.

−199·8	2·31	50·6	Charging volts 1·434
−175·0	3·50	76·7	
−156·0	5·35	117·2	
−147·2	6·25	137·0	

The dielectric constants of these caustic potash and caustic soda solutions are given in fig. 5.

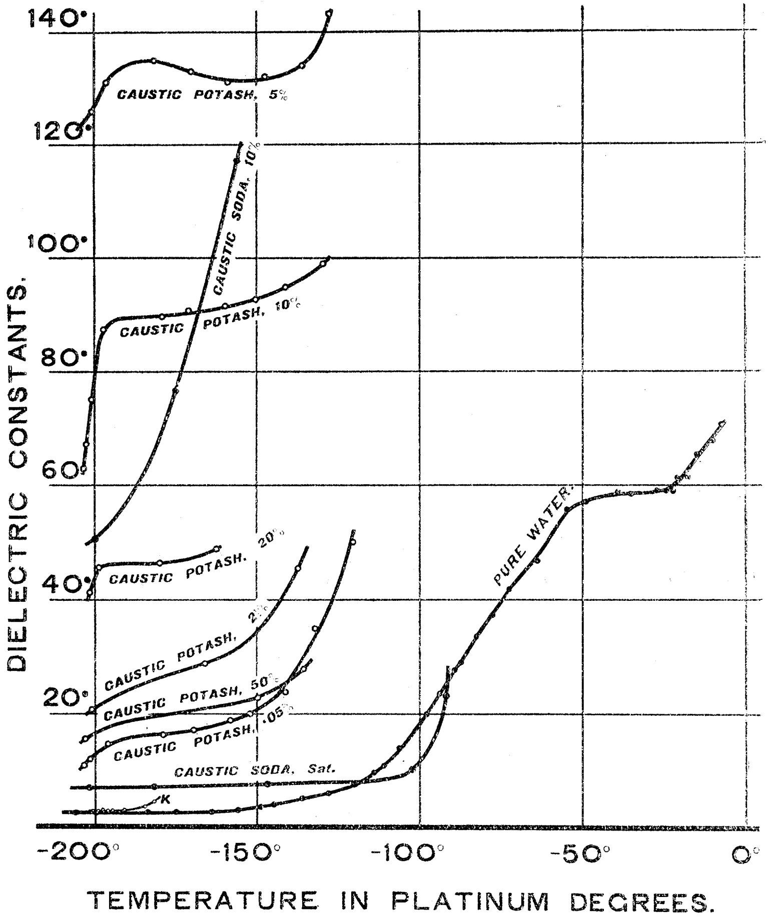

Fig. 5.—Curves showing the variation of dielectric constant of frozen caustic alkali solutions with temperature.

On examining these values for the dielectric constants of the frozen caustic alkali solutions, it will be seen that there is a remarkable difference between these last bodies and the other electrolytes examined by us, in that the values of the dielectric constant of the caustic alkalis are relatively very high at the low temperature of liquid air. In this respect the 5 per cent. solution of caustic potash is especially remarkable. For the same temperature, viz., −185° C., and varying concentrations, the 5 per cent. solution of caustic potash shows a maximum value for the dielectric constant of about 130, whereas the dielectric constant of the sulphate of copper, chloride of sodium, potassic cyanide, perchloride of iron, sulphuric and hydrochloric acids at the temperature of liquid air all have values not far removed from 3. The dielectric constants of the caustic potash solutions thus preserve a high value until a very low temperature is reached. It is, however, clear from the diagrams that the curves representing these last constants are in each case bending downwards, and a very moderate further reduction of temperature would probably reduce the constant in these cases also to a low value.

We were desirous of seeing what effect the solvent had in the case of the caustic potash, and accordingly prepared a 5 per cent. solution of caustic potash in ethylic alcohol and examined this with the following result:—

Dielectric Constant of Alcoholic Solution of Caustic Potash.

(5 per cent. solution.)

Frequency of fork 120. Galvanometer deflection with air as dielectric of condenser = 3·44 cm. for 100 volts.

Temperature in platinum degrees.	Galvanometer deflection in centimetres.	Dielectric Constant.	Observations.
−199·2	10·15	2·86	Charging voltage 99·8.
−200·6	10·05	2·83	1000 ohms in series with
−197·8	10·40	2·93	galvanometer.
−197·0	12·45	3·53 ?	
		cooled again	
−196·3	9·77	2·75	Charging voltage 99·8,
−194·8	1·97	2·81	Charging voltage 19·8.
−191·0	2·05	2·92	1000 ohms in series with
−184·8	2·45	3·50	galvanometer.
−181·8	3·02	4·35	

The above observations are plotted in the short curve marked K in fig. 5.

It is thus seen that the 5 per cent. alcoholic solution of caustic potash behaves quite differently to the 5 per cent. aqueous solution and has a much lower dielectric constant at −185° C. The conductivity of the alcoholic solution rises so rapidly just above −185° C. that the dielectric measurements cannot be carried up very far, but as far as they go they show that the solution in water has an immensely greater dielectric value than the solution in alcohol at −200° and upwards.

The observations we have so far made lead us to the following conclusions:—

(i) Frozen electrolytes at low temperatures are capable of acting as dielectrics even in the case of those substances which in the liquid state and in aqueous solutions have relatively a very high electrolytic conductivity.

(ii) At temperatures not far removed below their freezing points, these electrolytes have dielectric constants of large value, and numerically of the order of that of ice or water at 0° C. or in some cases much larger.

(iii) The majority of these high dielectric values so far as observed are reduced to very much lower values (near to 3) when the dielectrics are cooled to, and below the temperature of, liquid air.

(iv) Certain aqueous solutions of potash retain their high dielectric values to nearly the liquid air temperature, but give indication of being reduced at lower temperatures to small values.

(v) Frozen electrolytes at very low temperatures have very great insulating power, but recover sensible conductivity with great rapidity at temperatures far below their melting points.

(vi) It appears probable that at the absolute zero of temperature all electrolytes become perfect non-conductors of electricity or have infinite resistivity, also that it is possible their dielectric constants may all be reduced to, and represented by, a number near to 2 or 3 at that temperature, that of a vacuum being taken as unity.

We are engaged in examining as many electrolytes as possible at low temperatures to test the validity of the above last inference. In conclusion, we have again to thank Mr. J. E. Petavel for much valuable assistance in the laborious work of taking these observations, a work which has necessitated frequently very considerable endurance, in consequence of the fact that such series of observations, when once begun, had to be continued often through the night without interruption until completed.

"On the Dielectric Constants of Pure Ice, Glycerine, Nitrobenzol, and Ethylene Dibromide at and above the Temperature of Liquid Air." By J. A. Fleming, M.A., D.Sc. F.R.S., Professor of Electrical Engineering in University College, London, and James Dewar, M.A., LL.D., F.R.S., Fullerian Professor of Chemistry in the Royal Institution, &c. Received May 6,—Read June 3, 1897.

In another communication we have described the instrumental appliances we are at present using in investigations on dielectric

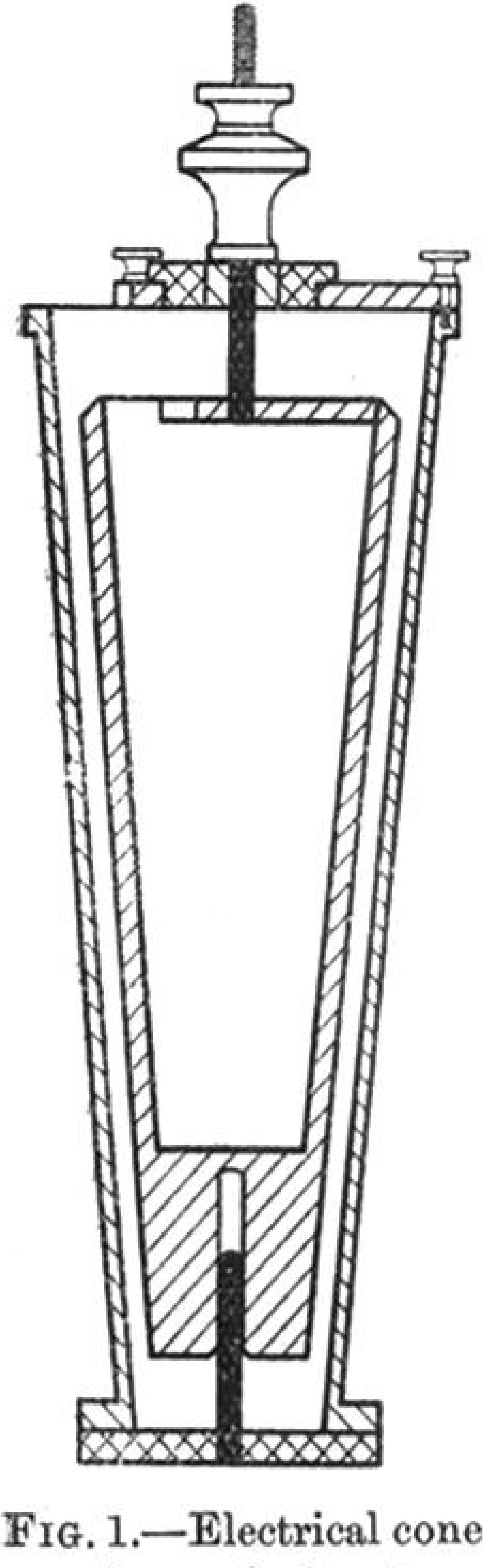

FIG. 1.—Electrical cone condenser for low temperature measurement of dielectric constant.

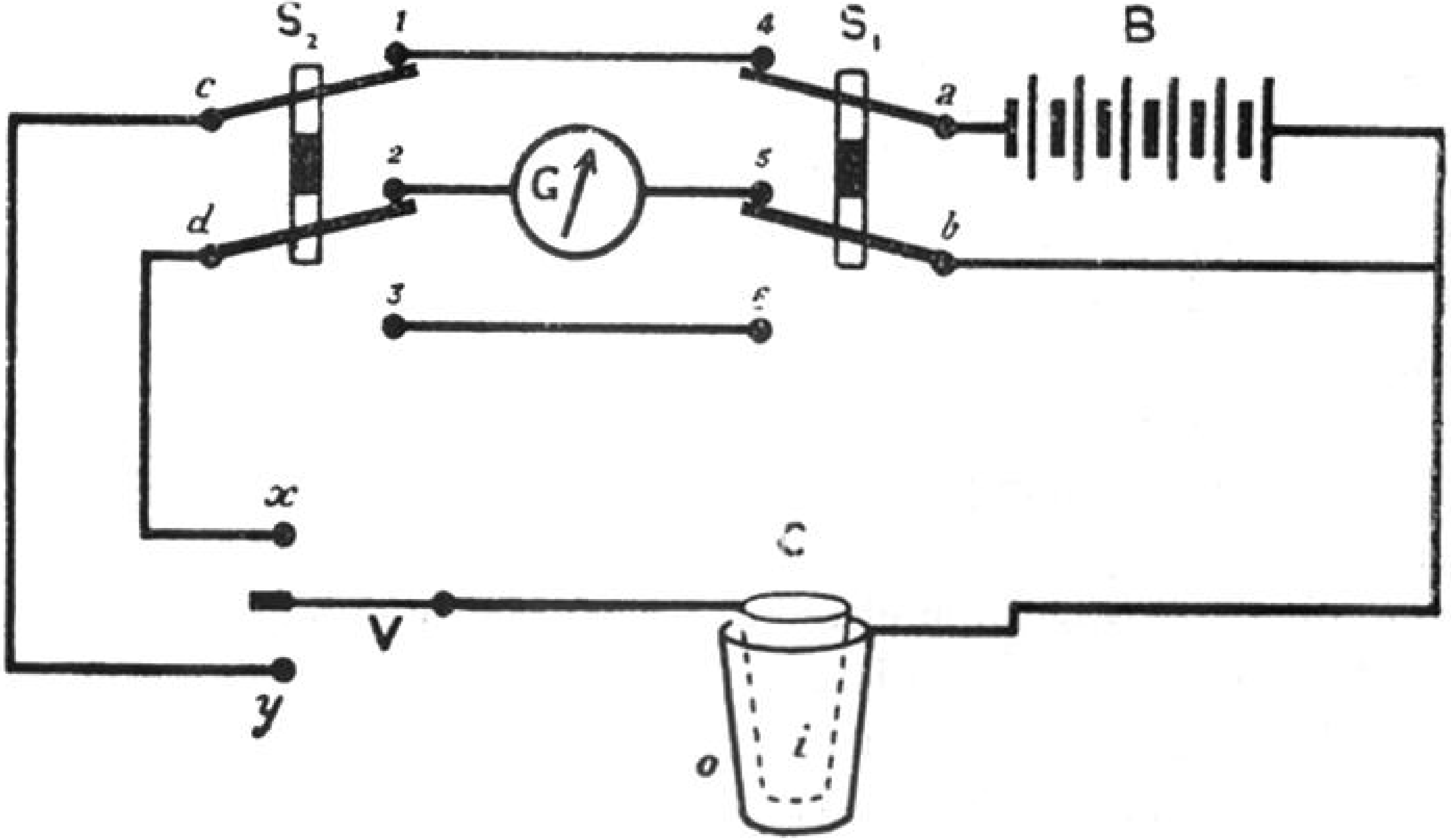

FIG. 2.—Arrangement of connections for measurement of dielectric constants. B, Battery of lithanode cells. G, Galvanometer. S_1S_2, Change-over switch. C, Cone condenser. V, Vibrating contact maker.